Energy Research and Development Division
FINAL PROJECT REPORT

COMMUNITY INTEGRATED RENEWABLE ENERGY PROJECT

Project Summary Report

Prepared for: California Energy Commission
Prepared by: Arup, for the San Francisco Department of the Environment

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PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The Energy Research and Development Division conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

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- Renewable Energy Technologies
- Transportation

The *Community Integrated Renewable Energy (Project Summary Report)* is the final report for the Community Integrated Renewable Energy project (contract number PIR-12-010) conducted by the San Francisco Department of the Environment. The information from this project contributes to Energy Research and Development Division's Renewable Energy Technologies Program.

For more information about the Energy Research and Development Division, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

ABSTRACT

Governor Jerry Brown called for 12,000 megawatts of renewable power to be generated within the local power distribution grid as part of the Clean Energy Jobs Plan. To reach the governor's goal, the state requires new models, such as community energy, that can be applied to a wide range of communities. Community-integrated renewable energy projects allow members of a community to have some or all of their electricity needs supplied from renewable sources. Communities that can pool resources to collaboratively exploit local renewable resources to supplement their energy needs can significantly leverage their individual investments to gain benefit from economies of scale in community energy systems. This energy may be supplied on an individual's property, via a credit from an off-site facility, or as part of a larger shared system installed within the community.

This report summarizes the work from a research project investigating a range of regulatory, technical, and economic constraints to increasing local, renewable energy in California. The team documented potential methods to increase the percentage of renewable generation supplied.

Keywords: community, renewable, energy, smart grid, microgrid, integration, utilities, district, thermal

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Introduction

California leads the country in the generating and distributing renewable power. The Renewable Portfolio Standard requires the state's utilities to procure 33 percent of their electricity demands from eligible renewable resources by 2020. As a next step to increase the California's ambitious renewable energy targets, Governor Jerry Brown called for 12,000 megawatts (MW) of distributed generation within the state. To reach 12,000 MW of additional localized energy generation by 2020, California requires new models, such as CIRE, applied to a range of communities including existing neighborhoods with multiple and diverse property owners.

Businesses, residents, and municipalities can pool resources to collaboratively exploit local renewable resources to supplement their energy needs and can significantly leverage their individual investments for economies of scale in community energy systems. Local renewable power is generation installed on the distribution network so that benefits are gained locally. Often these systems are installed right at the load point, maximizing the benefits such as reduced transmission losses. The projects are typically sized from 1 kilowatt (kW) to 20 MW and can be technologies such as photovoltaics, small wind, and biogas fuel cells.

The City and County of San Francisco's Community Integrated Renewable Energy (CIRE) Project assessed the feasibility of local, community energy, integrating district heating and cooling, renewable electricity, storage, demand response, and smart distribution technology to serve members of a community with their energy needs. A key feature of CIRE projects is electricity is generated and distributed within a community.

Project Purpose

The City and County of San Francisco CIRE Project explored the regulatory barriers that slow or impede implementing community scale projects and connecting them onto the electricity grid; and to identify or resolve ownership issues. Since 52 percent of San Francisco's greenhouse gas emissions are associated with lighting, heating, and cooling buildings, the City and County are committed to developing and implementing aggressive and diversified approaches to reduce these emissions while continuing to absorb anticipated regional population growth. One approach is to plan carbon-free community-scale energy resources locally and regionally. Another is to increase jobs and housing in transit-oriented neighborhoods.

The CIRE Project focused on the Central SoMa (South of Market) District - a dense, transit-rich area of San Francisco, identified for priority development by the Planning Department. The City and County have made a significant rezoning effort for SoMa to encourage sustainable growth and create substantial opportunities to align energy, transportation, water, and waste infrastructure systems.

Community-scale integrated renewable energy has rarely been undertaken in a multiple stakeholder context in the United States. One unique component of the CIRE system is that the project could require the distribution of energy resources to multiple stakeholders across public rights-of-way, which has traditionally been a barrier under California Public Utility Code. Project results will help determine the viability of such a bold step and provide significant California and international development opportunities.

Project Process and Results

Community-shared generation takes many forms and ownership models. Four CIRE models-were investigated to determine their different effects. Electricity generation was considered for all models, and the thermal studies were carried out only for models 3 and 4. The four models are:

1. Off-site generation – members of a community who have no on-site space for or access to renewable energy but who want renewable energy to supply their individual property/business.
2. Single-owner campus – a single, distributed campus community member, who is not located on a contiguous land parcel, who wants to install renewable generation behind their utility meter.
3. Multi-owner community – community members within a single contiguous or multiple land parcel whose energy is provided by on-site, centralized energy generation.
4. Microgrid – community members spread over multiple land parcels whose energy is provided by centralized energy generation and have the ability to separate from the wider grid and operate independently.

Not all locations and communities have sizable opportunities or suitability to be a CIRE project. Stakeholders during workshops determined ideal locations where community energy projects could be sited including parking garages and public road infrastructures. Other community energy projects, such as community wind, leasing space in a building, and microgrids were scored lower based on visual impact, inadequate generation potential, cost and/or technical and regulatory barriers.

Common barriers to renewable energy projects include ownership and risk considerations, electricity distribution and sale in the current regulatory environment. Several key themes emerged as impediments to CIRE projects, with the majority of barriers considered regulatory rather than technical. These barriers include:

- the inability to share power among several members of a community
- the requirement to become a regulated utility when distributing energy to more than two community members
- the ownership of generation and distribution assets
- existing utility business models and regulation

While a single-owner campus can offer some benefits for renewable development, the multi-owner communities and microgrids are the models providing actual opportunities for numerous CIRE projects and these can be replicated in California neighborhoods. In multi-owner communities, traditional investor-owned utilities and third-party developers were identified as suitable entities that can own and operate CIRE projects. Rates and regulations must be modified to allow the CIRE projects throughout California.

As part of the study, the team also investigated how renewable assets could be integrated with new and existing buildings and how their safety generators operate during grid outages in microgrid mode. The team's analysis quantified the size and capacity of generation and storage technologies required for three building sizes and types (single building, convention center, and mixed-use community) to be supplied by electricity from local sources for grid outages between five and 72 hours.

Fixed-output generation — diesel generators and/or fuel cells — is an important aspect for maintaining the resilience criteria identified in this report. This is due to the limited space that urban buildings and the surrounding areas have for the deployment of renewable generation and storage assets.

Thermal energy was studied at the multi-owner community level in two differing scenarios. Both thermal studies yielded positive results and energy benefits. The first study investigated how an existing steam district thermal system could become more efficient and reduce its energy footprint. Recommendations include integrating solar thermal, integrating groundwater recovery, increasing condensate recovery, and using combined heat and power. The second study was a feasibility study investigating a new district thermal system. Results showed comparable costs to the distributed model, environmental and social benefits.

Central SoMa Findings

The CIRE Project focused on the Central SoMa (South of Market) District – a region identified for priority development by the Planning Department to encourage sustainable growth and way to support energy, transportation, water, and waste infrastructure systems.

The team explored high-value sites for integration, which include parking garages and public road infrastructure. For parking garages, the team determined that electric vehicle charging can be integrated with photovoltaics. Central SoMa has the potential to increase PV installations nearly six-fold with this approach. Creating a central community thermal energy scheme was also found to deliver a variety of environmental and social benefits at comparable operational cost to the distributed (baseline) scheme. Further study might include a larger district analysis (more than one block) to determine potential for district-energy systems, and working with building owners and developers at the pre-feasibility stage to overcome barriers to concept buy-in.

The research and workshops demonstrated a clear demand for CIRE projects in California. CIRE projects present a real opportunity to reach and then exceed Governor Brown's 12,000MW target of clean, local, renewable energy.

The general conclusions from this research study are that CIRE projects are attractive to businesses and members of the community, have energy reduction and resilience benefits; however, ownership and existing California regulation remain challenges for these projects.

Project Benefits

The final CIRE Project deliverables provide a roadmap documenting the demand, barriers, and potential regulatory challenges to developing CIRE projects throughout California, using San Francisco's Central South of Market neighborhood as the use case.

Community members may benefit from the centralized generation by reduced energy bills, greater local control, or choice over type of energy supply (particularly renewable). Adding microgrid features to CIRE projects provides greater energy resilience for community members who value resilience.

California ratepayers could benefit by implementing community scale projects in the state and connecting them to the electricity grid. Potential estimated savings are:

- 750,000 GWH of electricity savings over the life of all implemented projects
- 12,000,000 therms of natural gas savings over the life of all implemented projects
- 152,000,000 tons of carbon dioxide equivalent emissions reduced over the life of all implemented projects
- 1,100,000 jobs created over the life of all implemented PV projects

CHAPTER 1: Introduction

In February 2012, the City and County of San Francisco (CCSF) Department of the Environment was awarded research funding from the California Energy Commission (Energy Commission) to formulate community-specific renewable energy development plans. The Community Integrated Renewable Energy (CIRE) Project was one of the winning proposals of this grant.

The CIRE Project assessed the feasibility of community energy, integrating district heating and cooling, renewable electricity, electricity storage, and smart distribution technology to serve members of a community with their energy needs.

Current research in the emerging microgrid market has focused on contiguous campus or military base applications for integrating many energy vectors. Campus and military applications where one owner develops its own localized system are limited and will have a small impact in increasing California's penetration of renewable, community-integrated energy systems. Reaching the governor's goal of 12,000MW of additional localized energy generation by 2020 requires new models, such as CIRE, that can be applied to a wide range of communities.

Community-scale smart-grid/microgrid-controlled renewable energy integration has rarely been undertaken in a multiple stakeholder/building effort in the United States or elsewhere in the world, from the project team's knowledge. The CIRE Project has carried out research to determine the feasibility and challenges of taking such a bold step that has significant development opportunities both in California and around the globe. One unique component of a CIRE system is that the project requires the distribution of energy resources to multiple stakeholders across public rights-of-way. The up-front predevelopment activities assessed the following significant barriers to and knowledge gaps in this approach:

- regulatory hurdles such as electricity distribution to multiple stakeholders and across public rights-of-way(CIRE models 2,3 and 4)
- energy dispatch across public rights-of-way to multiple stakeholders (CIRE models 2,3 and 4)
- grid control across a noncontinuous land boundary to multiple stakeholders (CIRE model 4)

1.1 Project Goals and Approach

The project has five main goals, which correlate to the project tasks outlined within this chapter:

- determine the regulatory barriers and cost implications of upgrading the distribution infrastructure to connect renewable projects of the community scale (Tasks 2a and 2b)
- identify an area within the study area where enabling technologies (both electricity and thermal energy vectors) could provide several communities' energy needs (Tasks 3a and 3b)

- identify suitable generation technologies and system sizes required to provide energy to three types of buildings in the study area for various time periods (Task 4)
- determine whether there is a greater opportunity to reduce the energy consumption of the existing district energy within the study area (Task 3b)
- explore additional thermal district energy opportunities; identify site-specific opportunities to integrate district with water and transportation infrastructure (Task 5)

This project investigates all of the components identified in **Figure 2**.

Figure 1: CIRE Project Study Areas

In San Francisco, 52% of greenhouse gas emissions are associated with lighting, heating, and cooling buildings. CCSF is committed to developing and implementing aggressive and diversified approaches to reducing these emissions while continuing to absorb anticipated regional population growth. One such approach is to plan carbon-free community-scale energy resources locally and regionally. Another is to increase jobs and housing in transit-oriented neighborhoods.

Central SoMa (South of Market) is a dense, transit-rich area of San Francisco that extends from Second Street to Sixth Street and from Market Street to Townsend Street. The area has been identified as a priority development area by the Planning Department and is the subject of a significant rezoning effort that encourages sustainable growth and creates substantial opportunities to align energy, transportation, water, and waste infrastructure systems (Figure 2). In addition to identifying the renewable energy resources and enabling technologies that could be appropriate for this district, the CIRE Project identifies ways CCSF can advance community-scale energy in this neighborhood. These efforts include providing a strategy to coordinate multiple public and private interests, including identification of all key institutional stakeholders and relevant regulatory frameworks.

Figure 2: San Francisco Central SoMa Study Area

Source: CCSF Planning Department

With the addition of the Central Subway along and under Fourth Street (now under construction and scheduled to begin operation in 2018), undeveloped or underdeveloped parcels in the transit corridor offer a major development opportunity. CCSF anticipates approximately 10,000 new housing units and 35,000 jobs in this area. The Central SoMa Plan, released in draft in April 2013, proposes rezoning this area for dense, transit-oriented, mixed-use growth and provides opportunities to capitalize on rezoning to incorporate district-level energy infrastructure (Figure 3).

Figure 3: San Francisco Central SoMa Plan

Source: CCSF Planning Department and Arup.
Note the area was originally titled the Central Corridor. This has since been changed to Central SoMa.

In addition to providing local energy, creating CIRE projects will greatly enhance the resiliency of Central SoMa. The ability to generate power and provide local energy for such services as producing potable water and treating sewage is essential for both the immediate and long-term recovery from a large earthquake or similar disaster.

The Central SoMa CIRE Project has the potential to inform similar planning efforts in other parts of the state, particularly those with new development areas, major infrastructure projects, or significant revitalization planned, as well as existing mature neighborhoods.

1.2 Community Integrated Renewable Energy

California leads the country in the deployment of renewable generation. California law, Renewable Portfolio Standard, requires state utilities to procure 33% of their electricity needs from eligible renewable resources by 2020.

As a next step aimed at raising even further the State's ambitious renewable energy targets, Governor Jerry Brown has called for 12,000MW of distributed renewable power to be generated by projects sized no larger than 20MWs.

While the California Energy Commission has been tasked to determine how this target might be allocated among various programs and geographic or utility areas, it is broadly expected to include MWs from existing rooftop and ground mount programs, e.g., the California Solar Initiative, Renewable Auction Mechanism, feed-in tariffs, and general renewable solicitations.

To put the 12,000MW number into perspective, the California Solar Initiative (designed to support installation of solar photovoltaic [PV] systems under 1MW) has a goal of 1,940MW of installed capacity by 2016 and, as of 2013, had reached the 1,659MW installed mark via approximately 160,000 installations since the program's launch in 2007 (Peterson, 2013). This 1,940MW target does not include publically owned utilities (which the 12,000MW target will apply to) but serves as a useful reference to the amount of renewable energy connections that could be required for small renewable energy systems.

In the context of this report, *local renewable power* is defined as generation installed on the distribution network so that benefits are gained locally. Such benefits include reduced system losses, energy security, deferred need for transmission lines, and increased renewable energy content. Often these schemes are installed right at the load point, maximizing these benefits. The projects are typically sized from 1kW to 20MW and can be technologies such as photovoltaics, small wind, and biogas fuel cells. A key feature of CIRE projects is that electricity is generated and distributed within a community, defined in this project as the Central SoMa redevelopment area in San Francisco's SoMa neighborhood.

Local community generation drastically shortens the distance between the location where energy is generated and the site where it is being used. This reduces the need for high-voltage transmission infrastructure upgrades and reduces the amount of energy lost through transmission from generation source to customer site. The reduced reliance on large, centralized, combustion-based generation for energy needs will also lead to a significant reduction in carbon dioxide emissions and habitat conservation.

Implementing CIRE projects will provide important advantages in California's drive for clean power — development of local resources, avoided costs of new intercity transmission or remote generation, additional consumer autonomy, greater resiliency, and reduced greenhouse gas emissions.

Broad support for CIRE calls for new approaches and coalitions among consumers, community leaders, utilities, and power providers. These new approaches have to address the needs and desires of key stakeholders — utilities, consumers, businesses, and residents — along with health and environmental factors. An influx of new local generation is likely to require revised utility business models as California transitions toward a new paradigm for its electrical grid.

1.3 CIRE Models

Four CIRE models were defined and investigated throughout the study period to determine their different implications with respect to public need, regulatory and technical challenges, and economics. Electricity generation was considered across all four CIRE models, while the thermal studies were carried out only for Models 3 and 4.

Community-shared generation can take on many forms and many ownership models. This report has considered the following scenarios:

1. Off-site generation – members of a community who have no on-site space for or access to renewable energy but who want renewable energy to supply their individual property/business.
2. Single-owner campus – a single, distributed campus community member, who is not located on a contiguous land parcel, who wants to install renewable generation behind their utility meter.
3. Multi-owner community – community members within a single contiguous or multiple land parcel whose energy is provided by on-site, centralized energy generation.
4. Microgrid – community members spread over multiple land parcels whose energy is provided by centralized energy generation and have the ability to separate from the wider grid and operate independently.

1.3.1 Model 1 – Off-site Generation

Approximately 75% of Californians cannot install renewable generation on their property or business (Denholm, 2008). This may be due to a variety of reasons such as lack of space, lack of access to a renewable resource, a tenant within a building, or lack of up-front capital or financial credit.

This CIRE model does not focus on an interconnected community. This CIRE model applies to any individual members of a community, who may or may not be physically adjacent to each other or to a renewable generating asset, but who have a desire to supplement their electricity with up to 100% renewable energy. The community member would like to purchase this energy from a provider of this renewable generation and have this credit applied to their energy bill. The community member and the generator do not have to be in the same neighborhood.

1.3.2 Model 2 – Single-Owner Campus

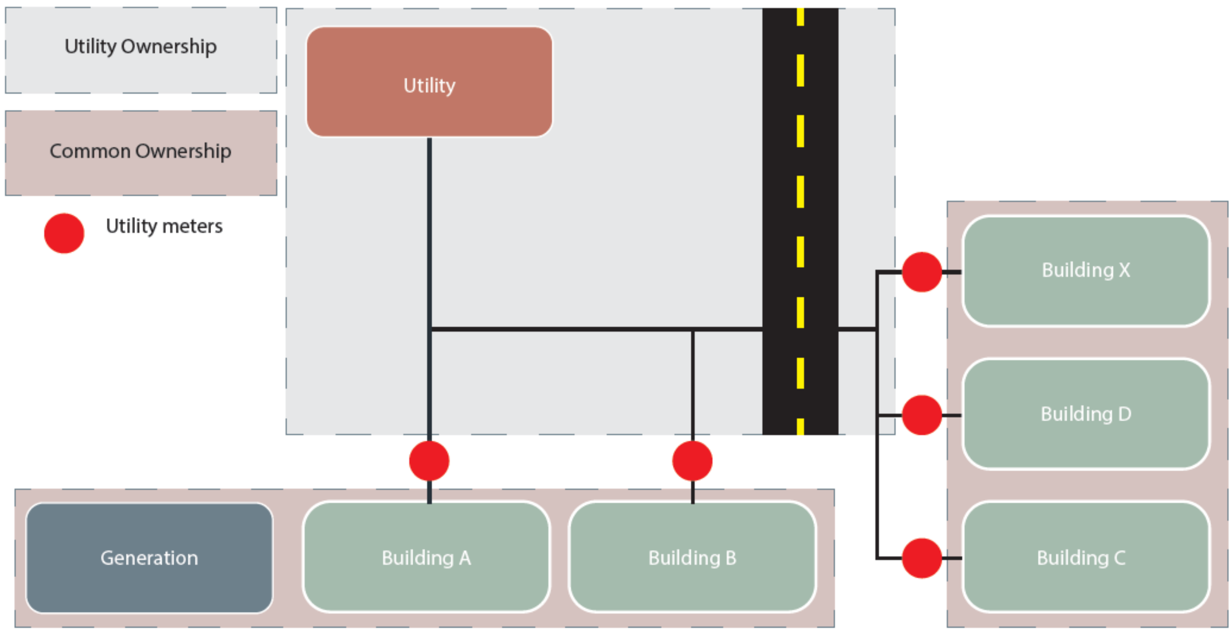
This CIRE model is a community that is not contained on one contiguous land parcel. There is one owner of the community, for example, a large corporation/business, a hospital, or a university (Figure 4). There are many such communities all over California. A number of companies have seen organic growth of their corporate campuses, which are often intermingled with public streets and served by utility infrastructure.

The noncontiguous community has many buildings. The campus owner has potential plans for expansion either by acquisition of existing local buildings or the construction of new buildings. All of the buildings typically have an individual utility connection, and the utilities distribution system distributes power to each building.

Each building has the opportunity for renewable generation[1] to be installed local to the building; however, constructing a renewable generator to provide power to all buildings in a single generator would allow the owner to maximize the generation and/or system efficiency to suit the demand of the buildings, for example, by installing an electricity-generating fuel cell.

A key feature of this CIRE model is that the community has a single ownership.

Figure 4: CIRE Model 2



1.3.3 Model 3 – Multi-Owner Community

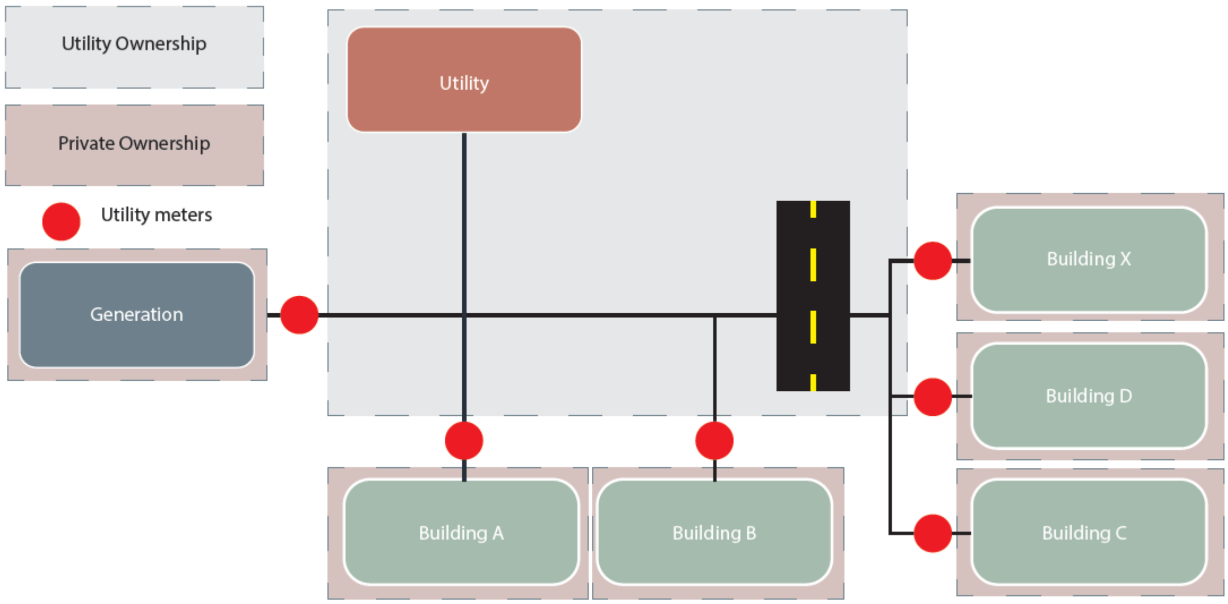
This model may be a designated eco-district, a large new development, an existing block, or the redevelopment of a city block such as is common in Central SoMa. The community may be made up of a mix of commercial and residential properties and a mix of building ownership and leases (Figure 5).

The CIRE project would involve installing a centralized generation plant[2]. The community members would share this centralized generation with all community members in the project area. The community members may benefit from the centralized generation by reduced energy bills, greater local control, or choice over type of energy supply (particularly renewable). With right-sized generation, the community could become a net zero energy community.

One ownership type within a multi-owner community is private ownership, shown in Figure 5 (another variation would be a utility ownership of generation).

[1] Such technologies include PV, directed bio-gas CHP, building integrated wind

Figure 5: CIRE Model 3 – Private Ownership



1.3.4 Model 4 – Microgrid

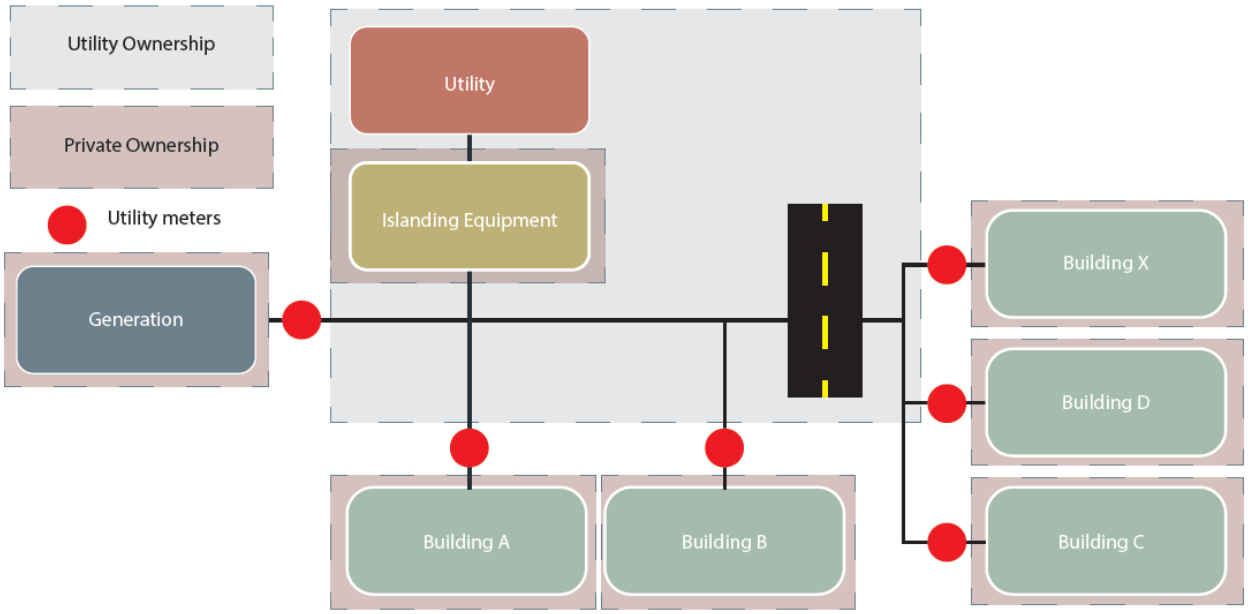
A microgrid in a CIRE context is an electric grid supplied from one utility distribution substation or feeder. This model has the same generation components as model 3, however this model can operate independently of the wider grid. The microgrid is self-sufficient — within the electrical grid there is enough energy generation and energy storage to support all of the loads, or at least the critical loads for large communities. The microgrid can separate from the wider grid, or "island," in times of wider microgrid outages.

This CIRE model describes a community that is spread over multiple city blocks. This may be a designated eco-district, a large new development or redevelopment of city blocks, or an existing neighborhood, all of which are common in Central SoMa. The community may be made up of a mix of commercial and residential properties and a mix of building ownership and leases.

The CIRE project would involve installing a centralized generation plant (electricity only, heat/cooling only, or heat/cooling and electricity). The CIRE project would share this centralized generation with all community members in the project area. The community members may benefit from the centralized generation by reduced energy bills, greater local control or choice over type of energy supply (particularly renewable), and potentially greater resiliency if designed to island during a grid outage, with the help of energy storage and smart grid controls. In addition to centralized generation there can be local behind-the-meter generation with communication links to the master microgrid controller. This model would enable the community to become a net zero energy community.

One ownership type within a microgrid is private ownership (Figure 6). A variation of this model would be a utility ownership of generation.

Figure 6: CIRE Model 4 – Private Ownership



1.4 Project Tasks and Scope

The project consists of the following reportable tasks:

- Task 1: Project Summary Report (this report)
- Task 2: Community-Distributed Generation
- Task 3: Community Energy and Enabling Technologies
- Task 4: Energy Storage and Generation Analysis
- Task 5: District Thermal Energy Concepts
- Task 6: CIRE Potential Quantification
- Task 7: Dissemination

A summary of each task is provided below:

1.4.1 Task 1 – Project Summary Report

The Project Summary Report is the overarching project report produced in December 2014. This report brought all of the findings from the 18-month research project together into a single report.

1.4.2 Task 2 – Community-Distributed Generation

This task was carried out between August 2013 and February 2014. The task covered two themes and was delivered in two project reports: Task 2a and Task 2b.

Task 2a – Regulatory Policy

- identify applicable codes, regulations, and standards to CIRE projects
- investigate the regulatory barriers to implementing a community-wide project
- work with the regulators and utilities to discuss concerns
- work with utilities to overcome any identified barriers with a mutually satisfactory solution
- review strategies to replicate CIRE throughout other areas of California

Task 2b – Technical and Cost Impacts

- report and map where network modifications are required in San Francisco's Central SoMa, providing data specific to San Francisco but applicable to other California distribution networks
- report on the utilities' technical engineering concerns about increasing renewable technology within an urban electricity distribution system
- present economic estimations for the works required to facilitate large-scale renewable penetration in urban distribution systems, which may be used as a guide/benchmark to inform other projects within California

1.4.3 Task 3 – Community Energy and Enabling Technologies

This task was carried out between October 2013 and April 2014. The task covered two themes and was delivered in two project reports: Task 3a and Task 3b.

Task 3a – Electricity Use Case

- Workshop to discuss renewable energy and microgrid scenarios in the study area. The scenarios were grouped under two broad topics: community renewable generation and enabling technologies to allow communities to operate independently of the grid. The workshop focused on the San Francisco's Central SoMa area as a case example within a broader state-wide context.

Task 3b – Heat Use Case

- The CIRE heat use case workshop engaged stakeholders from the city, the private district heating utility, and Arup. These stakeholders gave their insights into potential CIRE and non-renewable energy and resource performance improvement measures. The focus of the workshop was on San Francisco's existing district steam system, owned and operated by NRG.

1.4.4 Task 4 – Energy Storage and Generation Analysis

This task was carried out between March 2014 and June 2014.

The goal of this task is to conceptually identify suitable generation technologies and sizes that would be required to provide energy to the central corridor, through the following:

- conduct energy modeling and baseline establishment of stakeholder loads

- model energy generation options
- refine technical/regulatory challenges and financial implications of generation and storage
- present final concepts for energy generation and resiliency and energy storage
- model at least three energy storage options for the smart/microgrid to meet resilience criteria, including chemical/flow batteries, compressed and liquid air, and thermal energy storage

1.4.5 Task 5 – District Thermal Energy Concepts

This task was carried out between April 2014 and July 2014.

The goal of this task is to explore the feasibility of an additional San Francisco district thermal energy system.

- summarize the applicable codes, regulations and standards
- determine details of any permitting issues
- define the anticipated system loads served by the district energy plant
- identify the potential points of connection/responsibility to other community members
- determine the conceptual size of the district energy system and energy output
- provide the results of the cost implications and benefits of the district system
- Review how the proposed technology could be replicated across California

1.4.6 Task 6 – CIRE Potential Quantification

This task was carried out between September 2014 and October 2014.

This task demonstrates whether the implementation of CIRE technologies at the city and state level could have positive impacts on California's energy costs, environment, and employment numbers.

1.4.7 Task 7 – Dissemination

This task was carried out between December 2014 and February 2015.

This task will deliver dissemination via the following channels:

- a 1-hour webinar on the project summary report
- a website showing the results of CIRE technologies
- briefing sheets on the project results

CHAPTER 2:
Project Findings

This chapter provides the executive summary for each of the Tasks (2 through 6) that have formed part of this research project. Each of the reports in their entirety can be found in the Appendix and it is recommended that each individual report is read if more information than a high-level summary is required.

2.1 Regulatory Barriers for Community-Distributed Generation

2.1.1 Introduction

This summary provides the findings for Task 2: Community-Distributed Generation. The goal of Task 2a was to determine the regulatory barriers that prevent increased penetration of renewable distributed generation (DG) into the electricity network. This report is focused on assessing the regulatory challenges of increasing CIRE projects in California.

2.1.2 Project Purpose

Task 2a had the following scope:

- identify applicable codes, regulations, and standards to CIRE projects
- investigate the regulatory barriers to be overcome to implement a community-wide project
- work with the regulators and utilities to discuss concerns
- work with utilities to overcome any identified barriers with a mutually satisfactory solution
- review strategies to replicate CIRE throughout other areas of California

2.1.3 Project Results

Four CIRE models were defined and investigated for the regulatory challenges and barriers to implement in California. The majority of the CIRE models identified within Task 2a are generation projects that are not installed behind a single meter to exclusively serve on-site loads. Community-shared generation can take on many forms and many ownership models. Task 2a considers the 1.3 CIRE Models identified in Chapter 1.

Task 2a reviews California legislation applicable to CIRE projects and provides commentary on the impacts to the CIRE models. There are several barriers to implementing certain CIRE projects, including barriers to entry for both utility and private developer ownership of projects. These barriers include the following:

- the need to become a regulated utility when distributing energy to more than two community members
- the ownership of generation and distribution assets
- the existing electricity rate structure

- incumbent utility business models and regulation

The passing of Senate Bill (SB) 43 has created a regulatory path to allow individual property owners the opportunity to purchase clean, renewable power without having to install generation assets at their location. While SB 43 provides a pathway for individuals to obtain clean power, it does not present a local, community-wide solution.

In campus settings, the design of a new rate to allow shared campus generation will satisfy campus owners and also provide the existing investor-owned utilities (IOUs) with a revenue stream for the utilization of their assets. A rate such as this has the potential to increase CIRE projects at multi-parcel campuses, which are common throughout California.

While a campus rate for CIRE projects will provide a useful injection of CIRE projects, the real opportunity for proliferation of CIRE projects is in multi-owner districts and microgrids. Such systems can be constructed in every neighborhood in California. In multi-owner districts two suitable entities were identified that can own and operate CIRE projects. These are traditional IOUs and third-party developers. An IOU may be an obvious choice to develop these CIRE projects. Changes to rates and regulations are required, but in California's shifting regulatory environment, these changes do not seem unreasonable. Third-party ownership of CIRE models, while not possible in the current regulatory regime, would likely increase CIRE projects should legislation be changed to allow this model in California.

It is clear that CIRE projects are necessary for California and the most efficient method of increasing CIRE projects is to allow the development of CIRE projects by both the existing IOUs and competitive third parties. Rates and regulations must be modified to allow the proliferation of CIRE projects in California. The required changes to legislation are recommended to be publically researched in future Energy Commission PON's and consultations undertaken with all affected stakeholders. CIRE projects present a real opportunity in California to reach and then exceed Governor Brown's 12,000MW target of clean, local, renewable energy.

2.2 Cost Impacts of DG on the Distribution Network

2.2.1 Introduction

This summary provides the findings for Task2b and investigates the cost impacts of allowing DG onto the utility distribution network through the following methods:

- report and map where network modifications are required in San Francisco's Central SoMa, providing data that is specific to San Francisco but applicable to other California distribution networks
- report on the utilities' technical engineering concerns about increasing renewable technology within an urban electricity distribution system
- present economic estimations for the works required to facilitate large-scale renewable penetration in urban distribution systems, which may be used as a guide/benchmark to inform other projects within California

2.2.2 Project Purpose

Task 2b identifies the cost and technical barriers to deploying DG on the distribution network. In California, there are two predominant methods that utilities use to distribute power to customers:

- radial networks – common and simple distribution topology
- secondary networks – uncommon and complex distribution topology

A radial distribution network is the most common type of distribution network used by the majority of utilities in California. A secondary distribution network topology provides a far greater level of resilience for low-voltage customers. In a secondary distribution network, electricity is delivered through a complex and integrated system of multiple transformers and underground cables that are connected and operate in parallel. Due to the inbuilt redundancy in a secondary network, should a fault develop on an underground feeder or even a transformer, a customer would see no interruption in power as power would immediately flow from another part of the secondary network. Each customer within a secondary network has multiple levels of failure that can occur before the customer experiences a power loss. However, this added resilience can inhibit renewable energy interconnections.

To understand cost implications for connecting renewable energy, a series of case studies have been identified and discussions undertaken with PG&E to understand the cost and technical implications of the proposed case study. Task 2b considers the following scenarios:

1. Standard Distribution Network
    a. 100kW generation connection
    b. 500kW generation connection
    c. 1MW generation connection
    d. 10MW generation connection
2. Low-Voltage Secondary Distribution Network
    a. Low-voltage generation connection

2.2.3 Project Results

The following barriers and break points to community renewable energy development have been identified:

1. generation installed that is greater than 15% of the line's peak load
2. generation that requires distribution upgrades/back-feeds a utility transformer
3. any generation connection to the secondary network

During the feasibility process of any generation project, other than residential roof-mounted solar, it is recommended procuring a pre-application report. The pre-application report will provide all of the required information to estimate the likely interconnection costs and determine whether the project remains viable.

For secondary network connections, the challenges of connecting generation in these areas are due to the protection that these networks employ to remain safe. Standard utility interconnection requirements for generators connected to secondary networks require the generation to be sized at only 10% of the minimum load of the building interconnection point. Three potential solutions were investigated as part of this study to increase secondary network generation penetration:

1. Allow export toward 100% of minimum load for existing buildings with proof of minimum load for several years.
2. Install minimum import relay or a reverse power relay. This can ensure that generation is sized for a more typical building load profile and at the rare times of low load, controls can be installed on the customer side to curtail generation prior to the network protection operating.
3. Install a dynamic controlled inverter system to follow the building's load to prevent export.

A utility will assess each interconnection request in a secondary network on a case by case basis. The solutions may allow generation to be connected to the secondary network in excess of the current standard sizing of 10% of minimum load. In addition to utility assessment, the generation owner will make an economic assessment to ensure that with the required protection installed, the project does not become uneconomical.

2.3 Community Energy and Enabling Technologies – Electricity Use Case

2.3.1 Introduction

This summary provides the findings for Task 3a: Community Energy and Enabling Technologies – Electricity Use Case.

The goal of this task was to determine the market need, optimal locations, and regulatory barriers that prevent increased penetration of community-distributed generation into the electricity network. The task also investigates projects that can continue to operate when the grid is experiencing an outage condition. This report is focused on assessing the challenges to increasing CIRE projects in Central SoMa, in San Francisco, and statewide.

In the context of this report, *enabling technologies* are technologies that, should the grid power be lost due to an outage, will allow the community generation to continue to operate and provide power to the loads until the grid power is restored.

2.3.2 Project Purpose

The goal of Task 3a was to engage community members and stakeholders in order to understand their perspectives on and desire for CIRE systems via an interactive workshop and then draw insights from the workshop results and further project team analysis. The scenarios, organized into two broad categories and focused in Central SoMa, are:

- community energy scenarios
- enabling technologies to allow generation to operate in a grid outage

The workshop engaged stakeholders and collected feedback on the following topics:

- Community Energy
    - quantify baseline conditions
    - review market and locational needs
    - consider ownership and regulation
- Enabling Technologies
    - determine limitations of the existing infrastructure
    - review market and locational need
    - consider system functions
    - consider ownership of the assets

2.3.3 Project Results

The 24-square-block area that makes up Central SoMa in San Francisco is poised for significant growth, adding nearly 12,000 residential units and 9 million square feet of commercial space in the coming decade. This new growth may increase the existing electricity demand by over 40MW compared to current demand of just 90MW.

SoMa is not a community that has seen a significant penetration of renewable energy. The existing baseline of installed renewable energy totals just 2.6MW. There is the opportunity to change this and significantly increase the amount of renewable energy and enabling technologies installed in the community and other similar urban districts throughout California by implementing the scenarios that are discussed in Task 3a such as installing PV in parking garages.

Community Energy

Not all locations and communities have sizable opportunities or suitability for inclusion of CIRE projects. Task 3a has determined ideal locations where community energy projects may be sited. CIRE scenarios with the highest feasibility scores for the use of community space and energy need to demonstrate the optimum location for energy and/or storage assets in local communities. High-value sites for integration include parking garages and public road infrastructure. The Task 3 report details an assessment that was carried out in central SOMA to quantify the potential of roof top PV.

In a parking garage, it is recommended that electric vehicle charging be integrated with PV to provide the opportunity to charge electric vehicles directly from clean, renewable energy.

Central SoMa has the potential to increase PV installations nearly six-fold by this novel approach, which has been previously and successfully demonstrated at the San Diego Zoo. Garage owners can generate revenue from the sale of “priority” or “enhanced” parking spots, not electricity, and therefore comply with current regulations.

Integrating renewable energy into road infrastructure is being studied by the California Department of Transportation. There are some challenges in terms of cost, space take, and the additional safety measures that PV adjacent to the road entail; however, the opportunity is both compelling and significant.

Common barriers to CIRE implementation have included ownership and risk considerations as well as electricity distribution and sale in the current regulatory regime. Every community energy scenario has a theme of regulatory challenges in the sale and distribution of energy. Current regulations do not readily permit the sharing and sale of energy from one building owner to multiple other owners without the seller of electricity becoming a regulated utility.

There are significant regulatory barriers to transmitting energy across or within public rights-of-way and selling electricity to more than two adjacent properties. There is also a strong desire to maximize local renewable energy generation, but the most cost-effective and efficient mechanism for doing so would often involve sharing electricity with neighboring buildings. If the buildings are not under common ownership, which is often the case in traditional communities, the sharing of electricity is limited to no more than two community members on a contiguous land parcel. The research team recommends studies are performed with the Investor Owned Utilities (IOUs) and regulators to agree how best to progress a resolution and allow reasonable community-based renewable energy sources for citizens of California.

Should the buildings be in common ownership, there are emerging ways in which to share generation. Awareness of these programs has proven to be limited. Virtual net metering and aggregated net energy metering are two of the vehicles that will allow generation to be shared in multi-tenant or distributed campus/building settings. Outside of California, other utilities such as ConEdison are developing solutions to allow distributed communities under common ownership to share generation assets of up to 20MW. It is recommended that rates such as the Campus Rate in ConEdison’s territory are considered by regulators and utilities in California.

Enabling Technologies

When planning at the community scale, how to safely power an area of the existing grid while the wider power is unavailable is difficult. An orchestrator is required to manage all of the interfaces of supply, demand, safety, and eventual reconnection. This requires significant technical knowledge and is a job best suited to an existing IOU or third-party energy provider.

2.4 Community Energy and Enabling Technologies – Heat Use Case

2.4.1 Introduction

This summary provides the findings for Task 3b: Community Energy and Enabling Technologies – Heat Use Case. This task entailed the study of existing district heating systems in urban settings to explore the potential of CIRE and other energy and resource efficiency improvements.

NRG owns and operates a district heating system in downtown San Francisco (the system). This system is comprised of two energy centers that generate steam, and a 10-mile underground pipe network that distributes this steam to buildings in a two-square-mile area of the central business district of San Francisco

2.4.2 Project Purpose

The goal of this task was to engage in a collaborative workshop and collect feedback on the potential of CIRE in existing district heating systems. The task was carried out in collaboration with Arup, NRG, and CCSF, and culminated in a workshop to brainstorm and consolidate system improvement ideas.

2.4.3 Project Results

A benchmarking and potential improvement exercise was carried out using qualitative cost, benefit, and feasibility filters. The existing NRG district energy system in downtown San Francisco was studied as an example of such a system, so that a real benchmarking and potential improvement quantification exercise could be demonstrated. Opportunities for district energy thermal systems and potential benefits were then assessed for applicability to other locations. Potential improvements with the highest scores (feasibility, cost, and benefit) represent the recommended measures.

Renewable Fuel – Biogas and Biomass

Without clearly identified existing local biogas suppliers, direct biogas is currently an infeasible strategy for NRG to pursue. In-state and out-of-state biogas suppliers should be engaged on an ongoing basis to understand potential directed biogas market rates and so that the success of a "green energy customer" can be assessed.

Though NRG has considered biomass as an alternate fuel supply, its generation plants are spatially constrained and would not support multiple-day fuel storage capacity. However, a single-boiler retrofit to support tri-fuel capability (biomass in addition to the existing natural gas and diesel firing capability) would result in a more manageable fuel delivery and storage operation.

Solar Thermal System

Boiler feedwater preheating represents the most efficient integration configuration of solar thermal systems into the existing San Francisco district heating system. However, the NRG generation plants have limited rooftop area and some of the neighboring buildings to the south and west are taller than the generation plant, shading portions of this roof area. Together, these factors would greatly limit the size of such a solar thermal system, especially when compared to the magnitude of heat that is generated and distributed by the system.

Alternately, solar thermal systems could be integrated to heat condensate at a strategic location along the return path. One such location has been identified as the roof of the Moscone Center, where an unshaded solar thermal system with a much larger capacity could be installed. This concept is recommended for further study.

Condensate Recovery

The NRG system currently recovers between 12% and 15% of spent steam in the form of condensate returned to the central plant.

NRG is currently undertaking the expansion of the condensate recovery system, which will result in a recovery rate of approximately 50%. This expansion project will require a moderate capital cost but will result in a beneficial amount of potable water and energy use reduction.

Increasing the condensate recovery rate to approximately 75% represents a high cost for the San Francisco NRG system with only a moderate water and energy reduction benefit. This is due to the significant condensate recovery infrastructure that would need to be added to reach customers that are not only farther away, but that will return incrementally smaller amounts of condensate to the generation plant.

Pipe Insulation and Repair

The NRG system distribution consists of approximately 10 miles of piping that connects the two NRG stations to its customers. Approximately 8% (61,000,000lbs) of all steam generated is currently lost through the distribution piping network due to leaks. Maintenance and improvement of the distribution system require identification and repair of distribution sections causing these losses. This is seen as a feasible but "moderate" cost and benefit exercise.

Combined Heat and Power

NRG is currently planning a CHP project scheduled to begin operation by mid-2014. The 500kW CHP project will include two 250kW generators that will meet 80% of the system electrical consumption, including an on-site reverse osmosis plant used by the system. The heat generated in the electricity generation process will be utilized for boiler feedwater preheating, offsetting boiler firing natural gas consumption.

An alternate to this scheme could entail a larger CHP plant, sized to meet the thermal base load of the plant, in which case excess electrical generation would need to be sold back to a local off-taker such as a local utility. Further information about such a scheme can be found in CIRE Task 2: Community-Distributed Generation (Regulatory Policy) Report.

Groundwater Recovery

Groundwater recovery is an attractive strategy for NRG as there are three existing neighboring sites that are already actively removing groundwater. These sites are not only within close proximity of the NRG generation plant, they currently do not use the groundwater and instead drain it to the local sewer system.

Recycled Water

Upon maximizing condensate recovery, recycled water can be used in lieu of potable water for boiler feedwater in district steam systems. Similarly, in district cooling and power schemes, recycled water can be used in lieu of potable water for cooling tower makeup purposes.

The availability and pricing of "purple pipe"[2] in the vicinity of the generation plants will to a large degree dictate the feasibility of this strategy, and a "green energy customer" scheme similar to the one discussed for biogas supply should be explored if costs are prohibitive. Though typically high-quality, locally available recycled water standards should also be checked against the operating chemistry requirements of existing district schemes.

2.5 Energy Storage and Generation Analysis

2.5.1 Introduction

This summary provides the findings for Task 4: Energy Storage and Generation Analysis.

The goal of this task was to conceptually explore the potential electrical energy resiliency benefits that can be achieved for existing and/or new buildings through a mix of established and developing CIRE generation and storage technologies.

2.5.2 Project Purpose

The analysis is based on the study of real and indicative electrical loads for building-scale and community-scale developments. Short-term and long-term grid power outages were simulated along with 72 electrical generation and storage technology mixes using the HOMER Energy software package. These mixes were informed by known spatial and regulatory constraints such as realistic roof space availability and net metering generation capacity restrictions, and then compared on a resiliency-normalized financial performance basis to arrive at a set of generation-storage mixes that inform the findings and recommendations in this report.

2.5.3 Project Results

In an effort to inform a range of building scales and technologies, this study considered 72 scenarios, which consisted of combinations of the following:

- 3 scale scenarios
    - convention center scale
    - single-building scale
    - community scale
- 2 resilience scenarios
    - 5-hour outage
    - 72-hour outage

[2] Industry term for pipe carrying recycled water.

- 12 generation and storage scenarios
    - Diesel, PV, and fuel cell generators
    - Lithium-ion and flow batteries along with liquid air energy storage

Fixed-output generation — diesel generators and/or fuel cells — is an important aspect for maintaining the resilience criteria identified in this report. This is due to the limited space that urban buildings and the surrounding areas have for the deployment of renewable generation and storage assets.

For scenarios with diesel generators during a 5-hour power outage, there is no need for storage to meet the electrical load. During a 72-hour power outage, the diesel consumption is limited to only 24 hours at full capacity. Therefore, larger storage capacities are necessary.

Lithium batteries, because of their high-energy density, are often more feasible in terms of size compared to liquid air storage or flow batteries. Lithium batteries also have higher round trip efficiency (90%) than both liquid air (70%) and flow batteries (85%). Lithium batteries are the most expensive of the studied storage technologies, while liquid air is the least expensive. These differences in cost have the largest impact on scenarios that require large storage capacities. While liquid air is the cheapest storage technology, it may not be suitable in an urban environment due to the industrial-aesthetic impact of the plant.

For some scenarios with fixed generation, HOMER calculated that energy storage is not required. However, HOMER is a model that assesses energy on an hour-by-hour basis and does not take into account the short-term fluctuations of energy generation and supply. Energy storage is likely required to ensure the stability of the microgrid for more scenarios than HOMER models can predict. Energy storage performs many important roles in a microgrid other than just purely storing electricity.

Comparing the results at the single-building scale and the community scale indicates that the cost of energy, in most cases, is lower at the community scale than at the single-building scale. In addition, the community scale, when compared to the single-building scale, has a feasible storage solution for each assessed generation technology. The single building could not result in a solution for the PVs-only scenario or for the fuel cell + PV scenario, while the community scale could offer a solution. Scale is therefore considered advantageous. Pooling both electricity demand and generation at the community level provides greater resilience opportunities and also economies of scale.

PV is an economic choice for California, particularly when installed at the community scale as modeled in this report. Fuel cell economics currently rely heavily on state and federal subsidies. However, fuel cells have not yet enjoyed the cost reductions that economies of scale have brought to the PV industry. Energy storage provides an essential service to a microgrid and the economics must be assessed on a case-by-case basis.

In addition to stationary electricity storage, electric vehicles could be used instead of stationary storage to provide microgrid support. This technology would be particularly suitable where there is fixed generation such as fuel cells and only a small amount of storage is required. A typical electric vehicle such as the Fiat 500e has a usable battery capacity of approximately 16kWh. Therefore, several vehicles would have to be plugged into a microgrid in order to make a meaningful contribution to the balancing of supply and demand.

2.6 District Thermal Energy Concepts

2.6.1 Introduction

This summary provides the findings for Task 5: District Thermal Energy Concepts and summarizes suitable district thermal generation, distribution, and recovery systems that provide reliable and efficient thermal energy to new and existing urban building developments, and do so with a significant contribution from renewable energy systems. A case study utilizing central heating and cooling with the application of heat recovery chillers was explored.

2.6.2 Project Purpose

The goal of this task is to conceptually explore the benefits of a shared community thermal energy system that can support a phased development of new urban mixed-use buildings within or adjacent to an existing community.

The analysis is based on the study of thermal loads of an indicative community-scale development. The hourly space cooling, space heating, and domestic water heating loads of the individual buildings in the indicative community were simulated using the Virtual Environment energy modeling package developed by Integrated Environmental Solutions (IES). These loads were then aggregated to arrive at the total concurrent hourly loads that a community energy system would be required to supply.

The community energy supply analysis was carried out using the District Energy Feasibility tool developed by Arup. This task involved the consideration of various district thermal schemes following the process established in the study entitled *District-Scale Energy Planning*.[3] System size, cost estimates, and economic implications were then established and documented for the preferred scheme.

2.6.3 Project Results – Indicative Case Example

The 24-square-block area that makes up Central SoMa in San Francisco is poised for significant growth, adding nearly 12,000 residential units and 9 million square feet of commercial space in the coming decade. New development has the opportunity to plan for heating, cooling, and domestic water heating systems, enabling cost effective-connections to a community thermal energy system.

The district thermal energy scheme studied in this report was found to have comparable capital costs and lower operating costs than the distributed (baseline) plant scheme. This is an intuitive and expected result for operational costs due primarily to the consolidation and optimization of operations and maintenance staff and activities, and secondarily due to the energy and resource

[3]Cornell et al., "San Francisco Smart Growth Implementation Assistance: District-Scale Energy Planning," San Francisco, April 2014.

efficiency achieved at scale. Together these results represent one of the main value propositions of district thermal energy.

However, this is an atypical result for capital costs, which are typically higher for a district thermal scheme than for a distributed thermal plant scheme. The expected capital cost premium is usually driven by distribution, which in the case of the scheme studied in this task was limited to one city block. The district thermal system studied therefore did not entail expensive major street crossings and lengthy trenching in busy public rights-of-way, driving the capital costs down to the point that the district and distributed thermal schemes are comparable. Cities and districts exploring multi-city-block distribution are likely to find that the district thermal energy scheme entails a significant capital cost premium over the distributed thermal scheme.

The district thermal energy scheme studied was also found to deliver monetary and non-monetary environmental benefits over the distributed thermal energy scheme. Reductions in energy and water consumption are demonstrated and are closely tied to the chosen district thermal technology of central heating and cooling with the application of heat recovery chillers. The district thermal energy scheme also demonstrates a subsequent reduction in carbon emissions and the consolidation of on-site emissions and refrigerants.

A life cycle analysis of all capital, operational, and monetary environmental costs demonstrates that the studied district thermal energy scheme has the potential to deliver a net present cost reduction on the order of 20%. However, the study also identifies significant hurdles that a community will have to overcome in order to realize such savings. Perhaps the most challenging of these is to bring together building owners and developers to achieve buy-in on the concept of shared thermal resources and the release of their control. This represents a fundamental paradigm shift in the way building owners and developers think about building heating and cooling utilities, and as such requires focused discussion and attention at the pre-feasibility stage.

The creation of a central community thermal energy scheme was also found to deliver social benefits such as unlocking the potential for shared community and public spaces across the district. These include indoor and rooftop spaces, which have the ability to transform the urban aesthetic and enhance its vibrancy. The scale of supply achieved by aggregating the demands of a community also unlocks certain technologies that are typically not feasible at the scale of single buildings.

Finally, the district thermal energy scheme is shown to enable greater thermal and electrical CIRE integration than can be achieved under a distributed thermal energy scheme.

2.7 CIRE Potential Benefits Quantification

2.7.1 Introduction

This report provides the findings for Task 6: CIRE Potential Quantification and summarizes the rough order of magnitude (ROM) environmental and economic benefits of implementing the CIRE technologies described in Tasks 2 through 5. The benefits are estimated for several large

California cities and the state as a whole to communicate the ROM of potential benefits at the state level.

2.7.2 Project Purpose

The goal of this task is to demonstrate the ROM of the potential environmental and economic benefits that could be achieved through state-wide adoption of CIRE technologies.

2.7.3 Project Results

This task demonstrates that the implementation of CIRE technologies at the city and state level could have a positive impact on California’s energy costs, environment, and employment numbers as follows:

- an estimated 750,000 GWH of electricity savings over the life of all implemented projects
- an estimated 12,000,000 therms of gas savings over the life of all implemented projects
- an estimated 152,000,000 tons of carbon dioxide equivalent emissions reduced over the life of all implemented projects
- an estimated 1,100,000 jobs created over the life of all implemented PV projects

CHAPTER 3: CONCLUSION

3.1 Investigated CIRE Models

CIRE projects allow members of a community to have some or all of their electricity needs supplied from local renewable sources.

In the context of this report, local renewable power is defined as generation installed on the distribution network so that benefits are gained locally. Such benefits include reduced system losses, energy security, deferred need for transmission lines, and increased renewable energy content. Often these schemes are installed right at the load point, maximizing these benefits. The projects are typically sized from 1kW to 20MW and can be technologies such as PVs, small wind, and biogas fuel cells. A key feature of CIRE projects is that electricity is generated and distributed within a community, defined in this project as the Central SoMa redevelopment area in the SoMa neighborhood in San Francisco.

Four CIRE models were identified and investigated throughout the study period to determine their different implications with respect to public need, regulatory and technical challenges, and economics. Electricity generation was considered across all four CIRE models, while the thermal studies were only carried out for models 3 and 4.

Community-shared generation can take on many forms and many ownership models. This report has considered the following scenarios:

1. Members of a community who have no on-site space for or access to renewable energy but who want renewable energy to supply their individual property/business.
2. A single, distributed campus community member, who is not located on a contiguous land parcel, who wants to install renewable generation behind their utility meter.
3. Community members within a single contiguous or multiple land parcel whose energy is provided by on-site, centralized energy generation.
4. Community members spread over multiple land parcels whose energy is provided by centralized energy generation and have the ability to separate from the wider grid and operate independently (microgrid).

3.2 CIRE Need and Electricity Generation Challenges

The research and workshops convened as part of this project demonstrated that there is a clear need for CIRE projects in California. CIRE projects present a real opportunity in California to reach and then exceed Governor Brown’s 12,000MW target of clean, local, renewable energy.

Not all locations and communities have sizable opportunities or suitability for the inclusion of CIRE projects. Task 3a, via a workshop process with 38 stakeholders, determined ideal locations where community energy projects may be sited. CIRE scenarios with the highest feasibility scores for the use of community space and energy need demonstrate the optimum location for energy and/or storage assets in local communities. The group explored feasibility of the following scenarios: parking garage PV, leasing space in a building, public road infrastructure, community wind, commercial microgrid, residential microgrid, community microgrid, and a resilient transit network. High-value sites for integration include parking garages and public road infrastructure.

Common barriers to CIRE implementation have included ownership and risk considerations as well as electricity distribution and sale in the current regulatory regime.

Several key themes have emerged from this research project as inhibitors to CIRE projects and the majority of barriers are regulatory, rather than technical.

These barriers include the following:

- the inability to share power between several members of a community
- the need to become a regulated utility when distributing energy to more than two community members
- the ownership of generation and distribution assets
- incumbent utility business models and regulation

The passing of SB 43 has created a regulatory path to allow individual property owners (CIRE Model 1) the opportunity to purchase clean, renewable power without having to install generation assets at their location. While SB 43 provides a pathway for individuals to obtain clean power, it does not present a local, community-wide solution.

In campus settings (CIRE Model 2), the design of a new rate to allow shared campus generation will satisfy campus owners and also provide the existing IOU with a revenue stream for the utilization of their assets. A rate such as this has potential to increase CIRE projects at multi-parcel campuses which are common throughout California.

While a campus rate for CIRE projects will provide a useful injection of CIRE projects, the real opportunity for proliferation of CIRE projects is in multi-owner districts and microgrids (CIRE models 3 and 4). Such systems can be constructed in every neighborhood in California. In multi-owner districts two suitable entities were identified that can own and operate CIRE projects. These are traditional IOUs and third-party developers. Rates and regulations will need to be modified to allow the proliferation of CIRE projects in California. The required changes to legislation are recommended to be publically researched via a future Energy Commission PON and consultations with all involved stakeholders undertaken.

The above regulatory challenges were deemed by the research team to be the greatest barrier to implementing CIRE projects. Technical challenges do exist and the project team discussed typical project concerns with PG&E. Analyzing the interconnection process, timelines, and potential improvements was beyond the scope of the research study. Instead the team focused on identifying the break points where connecting generation to the distribution system involved a significant cost. The following technical interconnection barriers and break points to community renewable energy development have been identified:

- generation installed that is greater than 15% of the line's peak load
- generation that requires distribution upgrades/back-feeds a utility transformer
- any generation connection to a secondary/spot network

During the feasibility process of any generation project, other than residential roof-mounted solar, the project team would recommend procuring a pre-application report. The pre-application report will provide all of the required information to be able to estimate the likely interconnection costs and determine whether the project remains viable.

For secondary network connections, the challenges of connecting generation in these areas are due to the protection that these networks employ to remain safe. Standard utility interconnection requirements for generators connected to secondary networks require the generation to be sized at only 10% of the minimum load of the building interconnection point. Three potential solutions were investigated as part of this study in order to increase secondary network generation penetration:

1. Allow export toward 100% of minimum load for existing buildings with proof of minimum load for several years.
2. Install minimum import relay or a reverse power relay. This can ensure that generation is sized for a more typical building load profile and at the rare times of low load, controls can be installed on the customer side to curtail generation prior to the network protection operating.
3. Install dynamic controlled inverter system to follow the building's load to prevent export.

A utility will assess each interconnection request in a secondary network on a case-by-case basis. The solutions may allow generation to be connected to the secondary network in excess of the current standard sizing of 10% of minimum load. In addition to utility assessment, the generation owner will make an economic assessment to ensure that with the required protection installed the project does not become uneconomical.

3.3 Renewable Microgrids

As part of the study, the team investigated how renewable assets could be integrated with new and existing buildings and their life safety generators to operate in times grid outages in microgrid mode.

The analysis team then quantified the size and capacity of generation and storage technologies required to allow three scales of buildings (single building, convention center, and mixed-use community) to be supplied by electricity from local sources for grid outages of 5 and 72 hours. The team analyzed 72 differing combinations of generation and storage assets to determine the optimum (based on the cost per kWh of electricity) generation and storage mix to satisfy an outage criteria based on the available space of the assets in an urban environment.

The space-take considerations of generation technologies such as solar and electricity storage assets limit the electricity that can be produced and stored by these technologies. Therefore, fixed-output generation such as fuel cells or life safety diesel generators is required in order to meet the resilience criteria.

Fixed-output generation — diesel generators and/or fuel cells — is an important aspect for maintaining the resilience criteria identified in this report. This is due to the limited space that urban buildings and the surrounding areas have for the deployment of renewable generation and storage assets.

For scenarios with diesel generators during a 5-hour power outage, there is no need for storage to meet the electrical load. During a 72-hour power outage, the diesel consumption is limited to only 24 hours at full capacity. Therefore, larger storage capacities are necessary.

Lithium batteries, because of their high energy density, are often more feasible in terms of size compared to liquid air storage or flow batteries. Lithium batteries also have higher round trip efficiency (90%) than both liquid air (70%) and flow batteries (85%). Lithium batteries are the most expensive of the studied storage technologies, while liquid air is the least expensive. These differences in cost have the largest impact on scenarios that require large storage capacities. While liquid air is the cheapest storage technology, it may not be suitable in an urban environment due to the industrial-aesthetic impact of the plant.

Comparing the results at the single-building scale and the community scale indicates that the cost of energy, in most cases, is lower at the community scale than at the single-building scale. In addition, the community scale, when compared to the single-building scale, has a feasible storage solution for each assessed generation technology. The single building could not result in a solution for the PVs-only scenario or for the fuel cell + PV scenario, while the community scale could offer a solution. Scale is therefore considered advantageous. Pooling both electricity demand and generation at the community level provides greater resilience opportunities and also economies of scale.

In addition to stationary electricity storage, electric vehicles could be used instead of stationary storage to provide microgrid support. This technology would be particularly suitable where there is fixed generation such as fuel cells and only a small amount of storage is required.

3.4 Thermal Energy at the Community Scale

Thermal energy was studied at the district scale in two differing scenarios during this research. The first study investigated methods in which an existing steam district thermal system could become more efficient and reduce its energy footprint. The second study was a feasibility study investigating a new district thermal system in San Francisco.

3.4.1 Existing System

NRG owns and operates a district heating system in downtown San Francisco. This system is comprised of two energy centers that generate steam, and a 10-mile underground pipe network that distributes this steam to buildings in a 2-square-mile area of the central business district of San Francisco. These buildings, or "steam customers," utilize the steam for a variety of uses including the following:

- space heating
- domestic hot water
- industrial processes
- air conditioning

Established in 1930, the system was originally owned by PG&E and was comprised of five separate systems. Continual system growth and interconnection led to the eventual consolidation into the two existing energy centers. NRG Thermal (a wholly owned subsidiary of NRG Energy Inc.) bought the system in 1999.

A benchmarking and potential improvement exercise was carried out using qualitative cost, benefit, and feasibility filters. The existing NRG district energy system in downtown San Francisco was studied as an example of such a system, so that a real benchmarking and potential improvement quantification exercise could be demonstrated. Opportunities for district energy thermal systems and potential benefits were then assessed for applicability to other locations. Potential improvements with the highest scores (feasibility, cost, and benefit) represent the recommended measures. Improvements that were studied included the following:

- renewable fuels
- solar thermal preheating
- condensate recovery
- pipe repair and maintenance
- combined heat and power
- ground water recovery
- recycled water

Many of the above technologies are suitable for existing district energy plants and indeed are being implemented at the San Francisco system. The research team identified that solar thermal, 50% condensate recovery, combined heat and power, and ground water recovery were the most attractive options.

3.4.2 New District Energy System

The district thermal energy scheme studied in this report was found to have comparable capital costs and lower operating costs than the distributed (baseline) plant scheme. This is an intuitive and expected result for operational costs due primarily to the consolidation and optimization of operations and maintenance staff and activities, and secondarily due to the energy and resource efficiency achieved at scale. Together these results represent one of the main value propositions of district thermal energy.

However, this is an atypical result for capital costs, which are typically higher for a district thermal scheme than for a distributed thermal plant scheme. The expected capital cost premium is usually driven by distribution, which in the case of the scheme studied in this task was limited to one city block. Therefore, the district thermal system studied did not entail expensive major street crossings and lengthy trenching in busy public rights-of-way, driving the capital costs down to the point that the district and distributed thermal schemes are comparable. Cities and districts exploring multi-city-block distribution are likely to find that the district thermal energy scheme entails a significant capital cost premium over the distributed thermal scheme.

The district thermal energy scheme studied was also found to deliver monetary and non-monetary environmental benefits over the distributed thermal energy scheme. Reductions in energy and water consumption are demonstrated and are closely tied to the chosen district thermal technology of central heating and cooling with the application of heat recovery chillers. The district thermal energy scheme also demonstrates a subsequent reduction in carbon emissions and the consolidation of on-site emissions and refrigerants.

A life cycle analysis of all capital, operational, and monetary environmental costs demonstrates that the studied district thermal energy scheme has the potential to deliver a net present cost reduction on the order of 20%. However, the study also identifies significant hurdles that a community will have to overcome in order to realize such savings. Perhaps the most challenging of these is to bring together building owners and developers to achieve buy-in on the concept of shared thermal resources and the release of their control. This represents a fundamental paradigm shift in the way building owners and developers think about building heating and cooling utilities, and as such it requires focused discussion and attention at the prefeasibility stage.

The creation of a central community thermal energy scheme was also found to deliver social benefits such as unlocking the potential for shared community and public spaces across the district. These include indoor and rooftop spaces, which have the ability to transform the urban aesthetic and enhance its vibrancy. The scale of supply achieved by aggregating the demands of a community also unlocks certain technologies that are typically not feasible at the scale of single buildings.

Finally, the district thermal energy scheme is shown to enable greater thermal and electrical CIRE integration than can be achieved under a distributed thermal energy scheme.

3.5 CIRE Potential Quantification

The final reportable task that the project team undertook was to estimate the environmental and economic benefits of three of the studies that were performed. This section summarizes the rough order of magnitude (ROM) environmental and economic benefits of implementing the CIRE technologies described in Tasks 2 through 5. The benefits are estimated for several large California cities and the state as a whole in order to communicate the ROM of potential benefits at the state level.

The goal of this task is to demonstrate the ROM of the potential environmental and economic benefits that could be achieved through state-wide adoption of CIRE technologies.

This task demonstrates implementing CIRE technologies at the city and state level could have a positive impact on California’s energy costs, environment, and employment numbers:

- an estimated 750,000 GWH of electricity savings over the life of all implemented projects
- an estimated 12,000,000 therms of gas savings over the life of all implemented projects
- an estimated 152,000,000 tons of carbon dioxide equivalent emissions reduced over the life of all implemented projects
- an estimated 1,100,000 jobs created over the life of all implemented PV projects

3.6 Recommend Future Research Activities

The overarching conclusions from this research study are that CIRE projects are attractive to businesses and members of the community, have energy reduction and resilience benefits, but are complicated in terms of ownership and existing California regulation.

This research project has identified where the regulatory barriers exist and touched on potential mechanisms for change. As there is a strong desire for CIRE projects it is recommended that the California Energy Commission focus on CIRE projects in future solicitations.

The Energy Commission has released a Program Opportunity Notice (PON) - PON-14-301 – "*Demonstrating Secure, Reliable Microgrids and Grid-Linked Electric Vehicles to Build Resilient, Low-Carbon Facilities and Communities.*"

Within this PON, the Energy Commission states that, "proposals must demonstrate low carbon-based microgrid technologies that: (1) protect critical facilities from service interruptions by providing reliable power; and (2) have high potential for energy and cost savings, in addition to environmental benefits." These objectives are features of the CIRE systems that are contained within the 6 reportable tasks that the project team produced.

The Energy Commission PON allows single-facility microgrid (CIRE Model 3) projects and microgrid projects that serve multiple customers over multiple properties and across public rights-of-way (CIRE models 2 and 4) to be eligible for funding.

In addition to the Energy Commission PON described above, it is also recommended a research project that investigates the regulatory and ownership barriers that were identified during this research study. The recommended scope of the project is to bring together the renewable energy industry, energy service providers, regulators, and electric utilities to review potential changes to regulations to allow CIRE projects to be implemented that share generation between buildings and/or cross public rights-of-way to resolve ownership and regulatory barriers. This research project concluded (in the majority of cases) that members of the community and most businesses want shared, local, renewable power to power their buildings and operations but would prefer not to be involved in the complex arrangements that would be required to own and operate such shared systems.

3.7 Other Research Work

The project team who completed this work will leverage the knowledge and understanding gained during this project to undertake a research project for the Department of Energy. San Francisco's solar+storage for resiliency project brings together a range of stakeholders, including municipal staff and policy experts, utility industry representatives, emergency responders, community-based organizations representative of their neighborhoods (such as churches) and city-wide anchor institutions (such as hospitals) working together to integrate solar and energy storage into a cities disaster preparedness plan to allow resilient microgrid zones.

Viewing disaster preparation and resiliency through the lens of on-going sustainability is fairly new in the emergency response arena. Like other cities working on issues at the intersection of sustainability and emergency preparation, CCSF faces the challenge of continuing to use its sustainable energy resources when the grid goes down. There are a range of technical and financial challenges including a lack of technical (specifically, renewable energy) background among emergency response planners, grid-islandable and energy storage equipment availability, linked emergency response and renewable energy funding sources, and competition for other emergency response priorities, such as securing robust post-disaster communications networks. The two year research work has the below objectives and the completed CIRE work can be leveraged for many of the objectives:

- Bring together a group of committed stakeholders to assist in preparing a solar+storage solution, integrated into a disaster preparedness plan.
- Understand the electricity needs of the existing disaster plans for San Francisco and other researched jurisdictions and areas, and understand which city buildings are used in disaster preparedness plans and list critical, essential, desirable, and nonessential power needs as well as determine the functions to be maintained during an extended power outage.
- Understand where in San Francisco buildings are located that have power needs as part of their disaster preparedness plans. Identify where buildings can be grouped together to form a microgrid and share power in the event of an extended outage.
- Produce a road map for San Francisco and the United States, along with four local case studies that demonstrate how microgrids, electrical storage, and islandable distributed solar systems can be implemented in communities throughout the country.
- Summarize and relate available existing financing methods to provide new innovative financing models that can be used nationally to allow solar+storage to be an integral component of disaster response planning.
- Develop a tool that can be used by a non-technical audience in order to assess what electrical loads are required to be maintained in the event of an extended outage.
- Understand what retrofit equipment may be required to allow existing buildings with solar+storage to operate in an extended outage.
- Test the recommendations for solar+storage with local stakeholders, refine recommendations in the solar+storage disaster recovery plan based on feedback.
- Produce a roll out plan of a solar+storage solution for San Francisco.
- Produce a best practice manual applicable across the United States where electricity continuity is important in disaster scenarios.

GLOSSARY

Term	Definition
behind-the-meter generation	Generation installed on an individual customer's electricity distribution system, behind the utility meter.
CCSF	City and County of San Francisco
CIRE	Community Integrated Renewable Energy
DG	distributed generation
eco-district	an urban planning tool that integrates objectives of sustainable development and reduces the ecological footprint of an area
IOU	investor-owned utility
kW	kilowatt
local renewable power	generation installed on the distribution network so that benefits are gained locally
microgrid	Microgrids are small-scale versions of the centralized electricity system. They include local generation and or energy storage. They achieve specific local goals, such as reliability, carbon emission reduction, energy arbitrage, diversification of energy sources. They have the ability to island from the wider grid and operate independently.
MW	megawatt
PG&E	Pacific Gas and Electric
PV	photovoltaics
ROM	rough order of magnitude
SB	Senate Bill
smart grid	A smart grid is a modernized electrical grid that uses information and communications technology to gather and act on information, such as information about the behaviors of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity
SoMa	South of Market

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APPENDICES

Appendix A: Task 2 Community Distributed Generation (Regulatory Policy)

Appendix B: Task 3B: Community Energy and Enabling Technologies Use Case - Existing District Heating Systems

Appendix C: Task 2: Community-Distributed Generation (Technical and Cost Impact Report)

Appendix D: Task 5- District Thermal Heating Concepts

Appendix E: Task 4- Energy Generation and Storage Analysis

Appendix F: CIRE Potential Quantification

Appendix G: Task 3A: Community Energy and Enabling Technologies Use Case - Electricity

These appendices are available as a separate volume, publication number CEC-500-2016-002-AP.